

IX. "On Stratified Discharges. VII. Multiple Radiations from the Negative Terminal." By WILLIAM SPOTTISWOODE, P.R.S., and J. FLETCHER MOULTON, F.R.S. Received June 16, 1881.

In our memoirs "On the Sensitive State of Vacuum Discharges" we have often alluded to, and even insisted on, the importance of the remarkable dissymmetry which manifests itself in electrical discharges in gases at low pressures. As the pressure is lowered this dissymmetry becomes more and more marked; the striæ themselves become individually unsymmetrical, and recede one by one into the positive terminal; the features which are associated with the negative increase in importance, until at last they occupy almost the entire area of the tube. The researches of De La Rue, Crookes, Goldstein, and others, have intended to increase the interest which attaches to the action which takes place at the negative terminal. And it is with a view of adding one more contribution to the interpretation of the phenomena of the negative discharge and the analysis of its nature and *modus operandi* that the present experiments are described.

On examining the image of a negative terminal as traced out in tubes of great exhaustion, by the phosphorescence due to Crookes' radiations, we have often noticed that the image was not a simple figure, but that more than one outline of the contour of the terminal might be traced. From the fact of the double contour having been first remarked, where the terminal was of a conical form, it was at first supposed that the second image might be due to internal reflexion, or to some property appertaining to the edge of the cone. But this supposition led to no satisfactory explanation of the phenomenon.

It was, however, thought that, inasmuch as the two images implied different systems of radiation, a magnet, suitably disposed, might affect them in different degrees, and thereby throw some light on their origin. For this purpose we used a large electro-magnet with its coils so coupled up as to give the two poles similar polarity. By bringing the two poles together, inclined at a moderate angle, a single pole and a field of great magnetic strength was produced.

The tube was then placed in the plane containing the axis of the two poles, and in the direction of a line bisecting their directions. The tubes first used were of great exhaustion, and were placed sometimes with the positive, sometimes with the negative terminal towards the magnet. When the tube was placed in a comparatively weak part of the field, the two images of the cone were seen in their usual positions relatively to each other, except that they were slightly more separated. But as the tube was brought gradually into a stronger part of the field, the two images became further separated, and by

degrees a third, a fourth, and even more images were brought out on the side of the tube. In one tube of very high exhaustion, for which we are indebted to Mr. Crookes, as many as eight images became visible.

The phenomena here described having been once clearly seen in tubes of high exhaustion, with conical terminals, and under the influence of a very powerful magnet, were afterwards distinguished in other tubes of less exhaustion, with other forms of terminal, and in a less powerful magnetic field.

In the absence of a magnet, the lines of radiation are approximately (though not exactly) normal to the surface of the negative terminal for all the images; and in a magnetic field their tendency is to follow the lines of magnetic force which pass through the point of issue from that surface. The effect of the magnet, therefore, whether the positive or the negative terminal of the tube is presented to the pole, is to direct the lines of radiation more nearly along these lines of force than they would be without its action; and since lines of weaker radiation would be more affected than lines of stronger radiation it follows that different images, formed by lines of different strength (or velocity of discharge) would be separated from one another by the magnet. A similar result would follow if they differed in other respects in their normal condition.

We have then, as an experimental fact, a series of images, each formed by a system of rays issuing from the surface of the negative terminal. The images being distinct, the system of rays must be distinct also. Now, as it seems hardly possible to imagine that, from every point of a surface, there can issue at one and the same instant of time a variety of systems of radiations, each system ranging over a finite angular distance, and each differently directed in space, we are driven to the conclusion that these radiations must have issued successively and not simultaneously from the terminal. In other words, the various images are formed in succession. Now, the entire series of images are present whenever a discharge passes through the tube; and when a "continuous" discharge (such as that from a Holtz machine) is passing, they are all as steady and as persistent as are any other features of the discharge. From this it follows that the radiations are not a continuous phenomenon, but that they are composed of a recurrent series of discharges, each having its own angular range, and its own direction in space; and as the electricity, which is the motive power, and the metallic terminal, which is the directing machinery, are the same in kind for each image, we are led to the conclusion that the positions of the images are determined by the force with which the radiations are projected. In fact, we understand that the various images are due to a succession of discrete discharges of successively diminishing strength.

The phenomenon of multiple images of the negative terminal as explained above has an important bearing on the nature of electrical discharges in vacuum tubes. For, if the phosphorising radiation consists of a recurring series of discrete discharges, the radiation in each series, and *à fortiori* the radiation as a whole, is discontinuous; and consequently the electrical discharge, to which it is due, must itself be discontinuous or "disruptive." We appear, therefore, in these phenomena to have an experimental proof, independent of and in addition to those adduced by Mr. De La Rue and others, of a fundamental point in the theory of these discharges, namely, their disruptive character.

The conclusion, that each main discharge consists of a series of minor discharges, has an interest as throwing light on a difficulty that may perhaps have been felt in respect of one of the conclusions in our second memoir. It was there shown that when the exhaustion was carried to a great degree of perfection, the negative part of the discharge showed signs of a "durational character;" and the difficulty consists in associating the character of duration with that of disruptiveness, as attributed to one and the same discharge. But if the explanation of the multiple images here suggested be correct, it may be possible to reconcile the two ideas by considering that the duration is to be understood not as implying a continuous process, but as measuring the interval from the commencement of each main discharge until the last of the series of minor discharges belonging to it.

This idea of rapidly recurring elemental discharges going to form a single discharge is very similar to the state of things which one of the authors of the present paper showed to take place in the case of a discharge from a coil. (See "Proc. Roy. Soc.," vol. 25, p. 73.) The revolving mirror showed that each discharge from the coil, though apparently single, and, if not instantaneous, at least continuous during the time it lasted, was, in fact, made up of a regular series of elemental discharges, each group of such discharges (constituting a single coil discharge) being composed of like elements. The phenomena above described go to show that even the so-called continuous discharge is made up of very rapidly recurring discharges, each of which is in its turn composed of a group of elemental discharges, the successive members of which bear definite relations to each other.